3.—PHYSIOGRAPHIC AND OTHER NOTES ON A PART OF THE SOUTH COAST OF WESTERN AUSTRALIA.

By

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CONTENTS.

ABSTRACT.

The paper discusses a strip of country, and the adjoining sea, stretching along the coast for about 600 miles, from Long Point to Israelite Bay, and extending inland from a few miles to about 50 miles. A general description of the area, its economics, and early settlement is given, including some mention of mining operations in the Ravensthorpe District, and the building of the first overland telegraph line from Adelaide to Perth.

Mention is also made of the continental shelf, the adjoining sea-floor, the tides and currents, and the Recherche Archipelago. These islands are basically of granitic rocks, but on some of them this is overlain by Coastal Limestone, which occurs on certain islands over the whole length of the archipelago. It is suggested that it was originally continuous, and probably represents the remains of the original coast of this part of the mainland, also that the formation of the archipelago was a relatively recent event, following the laying down of the Coastal Limestone.

Climate and rainfall are also discussed, and reference is made to a dry cycle, which has apparently affected a portion of the strip, during the last 25 years. After describing the soils and vegetation of the strip, the relationship between the rocks and resultant coastline is shown. The many wave-cut platforms, raised beaches and sea-built flats provide much interesting information about former sea-levels. Mention is also made of some remarkable caves in some of the gneissic hills, including a tunnel through Frenchman's Peak, and it is suggested that their formation may have been contemporaneous with that of the wave-cut platforms of Mt. Ragged and the Russell Range. The various Natural Regions, beaches, dunes, springs, and inlets are also described.

I. INTRODUCTION.

A. Area discussed.

This paper discusses a strip of country, and the adjoining sea, stretching along the coast of the State for about 600 miles from Long Point (about long. 116° 30′ E.) to Israelite Bay (about long. 124° E.) and reaching for distances varying from a few miles to 40 or 50 miles inland. It includes parts of more than one "zone," or "province," or "region," depending on whether it is being discussed from the botanical, agricultural, or geographical standpoint; we shall, for want of a better term and for the sake of brevity, refer to it as "the Strip."

B. General description.

The strip embraces a little of the Kalgoorlie Region, most of the Stirling Natural Region, and the south end of the Jarrah Region (Clarke, 1927, pp. 121–2, and 1936, pp. xi and xii). The westernmost sixth or so, in the Jarrah Region, composed almost entirely of Pre-Cambrian igneous and metamorphic rocks, stands, on the average, 800 or 900 ft. above the sea, and is, broadly speaking, a plain covered with heath and scrub and crossed by rather shallow but often steep-sided watercourses. Much of this plain is underlain by horizontally bedded sediments—the Plantagenet Beds of Miocene age—through which project hills of the Pre-Cambrian metamorphic and igneous rocks. Most of the hills slope rather gently down to the plain and do not rise more than than 100 or 200 feet above it, but the Stirling, Barren, and a few other ranges, are higher, and are steep and rugged. The plain rises gradually north of the Strip and forms part of the "Great Plateau of Western Australia," the average height of which is probably between 1,000 and 1,500 feet. (Jutson, 1934, p. 4).

Much of the coastline is rocky with many bold headlands alternating with sandy beaches. Behind some of the beaches are shallow inlets, most of which are cut off from the sea and are nearly dry. The sea fronting the eastern half of the Strip is dotted with small islands for 30 or 40 miles southwards ; the islands lying off the western half are few and rather close to the shore.

There is a superficial resemblance between the eastern plain, dotted with island-like hills, and the adjoining sea with its many islands ; but the plain is not all at one level, for in it, in different places, the more or less horizontal surfaces are at different heights above sea-level.

C. Acknowledgments.

From the time of J. S. Roe, the first Surveyor-General of Western Australia, surveyors, geologists, and others who have examined portions of the Strip have described some of its physical features and we shall refer to their contributions later. The physiography of two parts is discussed in detail by Jutson and Simpson (1917) and by Woolnough (1920). Our observations were made when investigating the Pre-Cambrian rocks and we have combined with our notes information from many sources which are all, we trust, acknowledged in the text. We were helped financially by a Commonwealth Research Grant, made available through the University of Western Australia, and we are greatly indebted to Mr. P. Stanley, Chief Draughtsman of the Lands and Surveys Department for the preparation of finished copies of the map and figs. 1 and 16, and to Dr. J. T. Jutson and Mr. E. S. Clarke, who read the manuscript of this paper and made many very helpful suggestions.

D. Historical Notes.

The population of the Strip is about 10,000 of which more than 8,000 live in or to the west of Albany. Perhaps the earliest settlement was at the end of 1826, when Major Lockyer arrived in King George Sound, after a seven-week passage from Sydney, with a small party of soldiers and convicts. It was only in the next decade that much real settlement began. At that time the chief activities were sealing and whaling, for which depots were established at Doubtful Island Bay, Cheyne Beach and Cape Riche ; also several small vessels (of the order of 100 tons) were built. In 1843 Albany's population had grown to 260, and the tonnage of shipping served was practically the same as Fremantle.

In the strip east of Albany, the rainfall is smaller, there are no forests, the soils are generally "lighter," and there has been much less settlement. We are much indebted to Miss M. Lukis, State Archivist, for the following information about settlement in this part.

It is interesting to note that when E. J. Eyre made his overland journey along the coast in 1841, he did not find any signs of settlement until he was within a few miles of King George Sound. When John Forrest made the same trip in the opposite direction in 1870, he did not approach the coast until he had crossed the Phillips River, but along the coastline from there to Eucla, the only two stations were Campbell Taylor's on the Oldfield River and Dempster's at Esperance. During the 70's several others were established and, west of the Oldfield, towards Albany, a number of isolated settlements were already in existence. In most cases it is only possible to give approximately the date of foundation of these stations, as it often happened that applications for pastoral leases were not made until the country had been tried out for a few years.

Warriups Station (about 40 miles N.E. of Albany). This was first taken up by the Wray family in the 70's, but later passed to the Hassells.

Cape Riche. The land in this district was originally taken up by George Cheyne, who however only used it as an out-station. Cheyne also had a large pastoral lease on the *Pallinup River* in 1847. The first permanent home near Cape Riche was set up by Cheyne's cousin Andrew Moir, who went there with his family soon after his arrival at King George Sound in 1844.

Bremer Bay. The first home was established here about 1860 by John Wellstead, who moved there from Albany with his large family. Both George Cheyne and T. B. Sherratt had bases for whaling in *Doubtful Island Bay* as early as 1837.

Jarramongup was originally taken up by Capt. John Hassell, probably in 1849, although there is no record of an application for a pastoral lease in the district by John Hassell until 1851 and the first mention of the name " Jarramongup " is in 1853.

Phillips River. The first settlers on this river were the Dunn Bros., who took up a lease in 1868 and built the old home at Cocanarup, which still stands.

Oldfield River. Campbell Taylor founded a station here in the 60's. In the early 70's he took a pastoral lease of a large area near *Cape Arid* and built the homestead " Lynbourne " on the *Thomas River*, where he lived and brought up his family.

Stokes Inlet and Fanny's Cove. A large pastoral lease bordering on these was taken up by John and Alexander Moir in the early 70's.

Esperance. The Dempster brothers established several stations in this district in the 60's. By 1870 they had settled at Esperance but formerly had a home at Mainbenup, about 25 miles to the west.

Israelite Bay. A large pastoral lease near Mt. Ragged was taken up in 1876 in the name of Stephen Ponton, and there were other leases in the district assigned to Ponton Brothers and Sharp (Stephen Ponton, William Ponton, John Sharp). The first lease of the land bordering Israelite Bay itself was issued in the name of an Albany settler, C. B. G. Heinzmann, in 1874.

Man has made little change in the original state of the Strip east of Albany, apart from a limited amount of settlement round Ravensthorpe, Hopetoun, and Esperance. As a port for the Goldfields, Esperance possesses many advantages, and there is some prospect that recent advances in methods of farming " light lands " may lead to closer settlement and greater productivity in this district.

The Strip has produced little in the way of mineral wealth, except near Ravensthorpe, where indeed there is hardly any mining activity now, but from which, since 1900, have come between eight and nine thousand tons of copper, about 88,000 oz. of gold and 16,000 oz. of silver. At Naendip, near the head of Dempster Inlet, is " an abandoned copper mine, several shafts of which tell . . . . . of Thomas Sherratt, who in the early 60's steered his cutter ' William and Mary ' into Point Charles and landed his party of prospectors " (Stevens,

1933), but we can find no record of the production of copper or any other mineral from Naendip. Manganese ore, graphite, and beach sands containing zircon have been prospected in several places, and about 600 tons of vermiculite have been taken from a formation in the Young River, 76 miles by track W.N.W. of Esperance.

A noteworthy achievement between the years 1875 and 1877, when Western Australia was a colony, was the erection of a telegraph line from Albany to Eucla, whence it connected with Adelaide. Miss Lukis has kindly allowed us to extract the following information from the State Archives :— The originator of the project was apparently J. C. Fleming, Superintendent of Telegraphs, but evidently C. D. Price, afterwards Assistant Surveyor-General, was very largely responsible for its success, for, in July, 1878, the thanks of the Legislative Council were conveyed to him " by the Speaker at the table on the floor of Parliament House " for " running the line " from Albany to Eucla. Although it was abandoned when the line following the Trans-Australian Railway was completed, many of the posts of " The Old Telegraph Line " still stand and are a valuable reference line for the geologist or geographer in this rather meagrely mapped country. The present-day traveller in these parts realizes that Stevens, in his interesting account (1933) of the construction of the line, has passed very lightly over the hardships and difficulties that must have been encountered in those days, when bullocks, camels, and horses were the only means of land transport.

II. THE SEA.

A. Sea Floor.

Information about the sea floor given on Admiralty Chart 2757b " corrected to 14th Dec., 1946 " shows that the 100-fathom line lies south of the coast at distances varying from 19 miles (south of Bald Island) to perhaps 42 miles (south of Cape Pasley), but soundings between Cape Knob and Israelite Bay are too few for this line to be indicated on the chart. Beyond the 100-fathom line or its approximate position, the floor slopes to depths of more than 1,000 fathoms, in most places at angles of 5° or less, but just west of Long Point, at about 20°, and inspection of the chart shows that elsewhere also it is probably steep. Details of shallow soundings near harbours, such as Esperance, show that the continental shelf has a very irregular surface, and Dr. D. L. Serventy (Fisheries Division, C.S.I.R.O.), tells us that its many irregularities make trawling impossible.

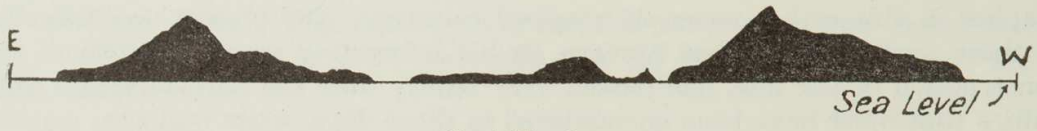
Soundings are not numerous enough to prove that any of the river valleys continue across the continental shelf, except the King-Kalgan (Jutson & Simpson, 1917, Pl. 1).

B. Islands.

The continental shelf which fronts the eastern part of the Strip carries many small islands—the Recherche Archipelago—which, together with the very numerous partly or wholly submerged rocks and reefs, are further evidence of the irregularity of the continental shelf. Between Cape Le Grand and Israelite Bay these islands and rocks dot the sea, extending southwards for 33 miles, but west of about long. 121° they are few, and lie close to the shore. Middle and Mondrain are the largest islands, and none, judging from available maps is more than from three to five miles in length or breadth.

The only island which we have personal knowledge is Thomas Island, situated about 7 miles east of Cape Le Grand. It is about three-quarters of a mile in length and approximately 150 feet high. Like many of the other islands, it is composed of gneiss and has no beaches. It is largely covered with heath and carries bushes and the ordinary coastal vegetation in the more sheltered places. Bechervaise (1951, p. 14) says : " All the islands without exception are basically of granitic rock, ... The granite reaches a considerable height on several islands, culminating in the peak of Mondrain (743 ft.). Only a little lower and much more abrupt is Remark (722 ft.) and the Twin Peaks both exceed six hundred feet." Many other heights of over 100 feet are given in " Australia Pilot." The highest of the western islands are Bald (1,020 ft.), Eclipse (400 ft.), Breaksea (384 ft.), Haul-off Rock (314 ft.), and outer Doubtful (246 ft.).

Many of the islands, as seen from the mainland, rise rather abruptly from the sea, but those about 5 miles E.S.E. of Duke of Orleans Bay appear, from a distance, to have platforms which are within reach of storm waves (text fig. 1).



Text Fig. 1.

Profile of islands about five miles E.-S.-E. of Duke of Orleans Bay.
H. T. Phillipps, Photo.

In addition to " granitic rock," Coastal Limestone (Clarke, Prider & Teichert, 1948, p. 286) occurs on a number of the islands of the Recherche Archipelago, from Boxer Id., 15 miles S.W. of Esperance, to Christmas Id., 25 miles S.E. of Israelite Bay (personal communication from Dr. D. L. Serventy). It is generally thought that Coastal Limestone has been formed along beaches where there is an ample supply of calcareous material, and it seems unlikely that conditions for such a deposit would exist along the shores of small islands in a rough sea. If this assumption is correct, then the Coastal Limestone occurrences in the Archipelago must once have been nearly continuous, and, when they have been mapped, it should be possible to link them together, and so reconstruct the once unbroken coastline. There will be some support for this suggestion if the apparent absence of Coastal Limestone from the mainland east of long. 120° E. is confirmed, and it will seem that, when the Coastal Limestones were being formed, the mainland of the eastern part of the Strip extended far south of its present position. It will also be clear that the formation of the Recherche Archipelago was a rather recent event which occurred after the building of the Coastal Limestone.

C. Currents and Tides.

The Southern Ocean near the south coast of Western Australia has been said to have a current moving westwards in summer, eastwards in winter, in harmony with the prevailing winds (see, for example, Gentilli, 1947, p. 19). However, in the " West Australian " newspaper of June 7, 1950, it is stated that " a spokesman of the Fisheries Division of the Commonwealth Scientific and Industrial Research Organisation said that bottles placed in the sea at Albany invariably were found to the east." Supporting this, as Dr. Serventy pointed out to us, " Australia Pilot," Vol. I, Third Edition, 1937, p. 23, states that there is an easterly current throughout the year " following the gen-

eral trend of the outer edge of the bank with depths of less than 100 fathoms," and also that from 116° to 120° E. " the average coastal current sets nearly due east, with an average rate of from 5 to 6 miles per day, throughout the year." " Australia Pilot," however, also refers several times to " reverse currents setting in a westerly direction " and Serventy pointed out (1937, pp. 66–68) that there are many departures from the generalization that the current flows eastwards. Thus, from 24th February to 2nd March, 1930, owing to engine failure, the trawler " Bonthorpe " drifted S.W. " at a rate varying from 12 to 25 miles per day." Serventy considered that these local currents, due no doubt to seasonal winds combined with the configuration of the shoreline, are probably important physiographical agents.

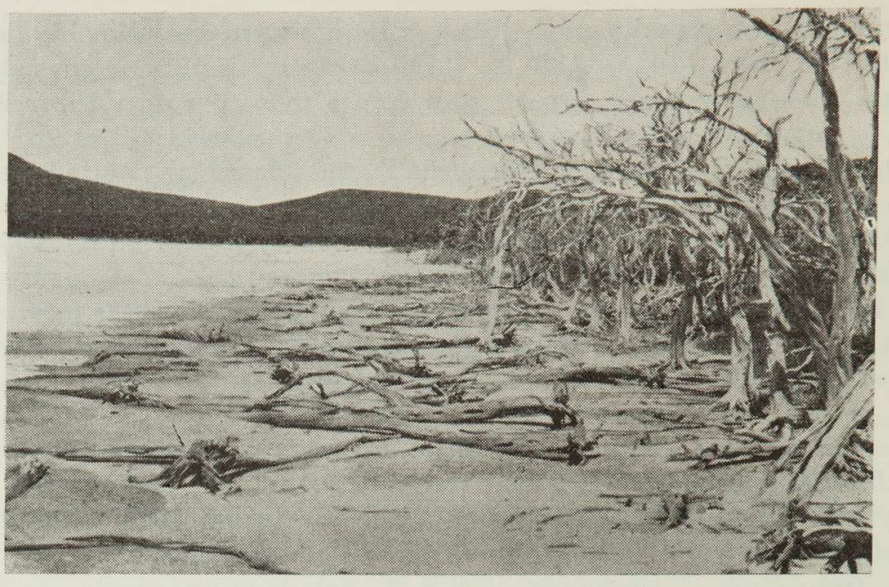
Regarding tides, Capt. A. Eggleston, for several years in command of vessels calling at various places along the south coast, has told us that between Albany and Eucla from January to March, the rise and fall is generally 2 ft. 6 in. but less if strong easterly winds prevail ; from March to June it is 2 ft. 6 in. ; from June to December, if a N.W. gale is approaching, the tide may rise 6 ft. or even more. We are also indebted to Capt. H. Griffiths, Harbour-Master at Albany, for the following statement :—" At Albany, barometric pressure seems to have great influence on the height of the tide. In summer, with high pressure, the tides are low; in winter, with low pressures, they are much higher. The average range at any period is 2 ft. 6 in. to 3 ft. The full effective range is about 5 ft., but a high tide of 5 ft. or so above zero would only fall to 2 ft. 6 in. or 3 ft. above zero, and, if the sea rose from zero, it would only go to about 2 ft. 6 in. There appears to be very little regularity about the tides, but there is one high and one low per day."

III. THE LAND.

A. Climate.

The Strip has a " cool " or " cool oceanic " climate, temperatures in the hottest months (January and February) being seldom above 72° F. The prevailing winds are easterly in summer, westerly with gales in winter. The average rainfall is about 20 inches. Most of the rain falls in winter, June, July, and August being the wettest months, each with about 5 inches (Taylor, 1918, p. 63 ; Gentilli, 1947, pp. 49, 93–104, 108–125, gives more recent data).

There can be no doubt that portion of the Strip, between Albany and Hopetoun, has been passing through a dry cycle during the last 25 years. Throughout that period the water-table at Doubtful Island Bay has fallen about 3 ft. and many of the inlets, which used to be open nearly every winter, have remained closed for ten years or more. In 1937 the Fitzgerald, Dempster, and Hamersley Inlets all contained a large quantity of water. Now all are dry, or nearly so, and at Dempster Inlet large paperbarks, possibly hundreds of years old, bordering the inlet, have perished (text fig. 2). Dr. D. Serventy informs us that between 1915 and 1920 the Hamersley Estuary contained large quantities of oysters and fish, including mullet, black bream, salmon trout, pilchards, flathead, and whiting, which were netted commercially. The estuary has remained closed since 1915, and by 1926–27 all the fish and mollusca had died, and although it has been more or less filled several times since then, it has not been open to the sea.



Text Fig. 2.

Dempster's Inlet in January, 1950. Salt-encrusted flat with dead paper-bark trees, which were alive in January, 1947.

A. Wilson, Photo.

B. Vegetation.

Jarrah forest, and to a small extent karri forest*, occupy the south-west corner of the Strip, i.e., the part which is in the Jarrah Region (Clarke, 1927, pp. 121–2). Gardner (1944, pp. xlii–iii and Pl. X) describes the jarrah forest as " a true sclerophyllous formation, remarkable for the paucity of other tree species," its only associates being *E. calophylla* (the marri or red gum) and *E. patens* (the blackbutt). Between these taller trees is a rather sparse undergrowth of shrubs and small trees, such as wattles and species of *Casuarina* and *Banksia* with the blackboy (*Xanthorrhoea*) and zamia (*Macrozamia Riedlei*). Jarrah is at its best on soils formed over laterite (Clarke, Prider, and Teichert, 1948, pp. 47–50) ; karri grows on soils directly " derived from the granitoid or gneissic rocks " (Gardner, 1944), which accounts for its occurrence on the lower country near the township of Denmark, and on isolated patches on the Porongorup Range and near Mt. Manypeaks. Gardner states that the karri forest contrasts strongly with the jarrah forest because of its larger trees, the karri and the tingles (*E. Jacksoni* and *E. Guilfoyli*), and because the undergrowth is denser and consists of broader-leafed trees and shrubs.

Gardner shows the eastern part of the strip as nearly all " sand-heath " (1944, Pl. X), which he describes as typical low heath with shrubs varying from 0.5 to 1 metre in height, though patches of taller shrubs and of small trees occur in many places (text fig. 22). There are small widely separated groups of the giant *Macrozamia Riedlei*, var. *Dyeri* between Esperance and Israelite Bay, both on the sand-heath and close to the sea, also the Western Australian Christmas-tree (*Nuytsia floribunda*) is common on the heath country, especially near Esperance. Shallow swampy depressions and small lakes (waterless for most of the year) are scattered over the heath ; in most of the swamps either paper-barks (*Melaleuca*) or Yate gums (*E. occidentalis*) are prominent ; in some places, near the coast, especially just east of Cape Arid, banksias are well represented.

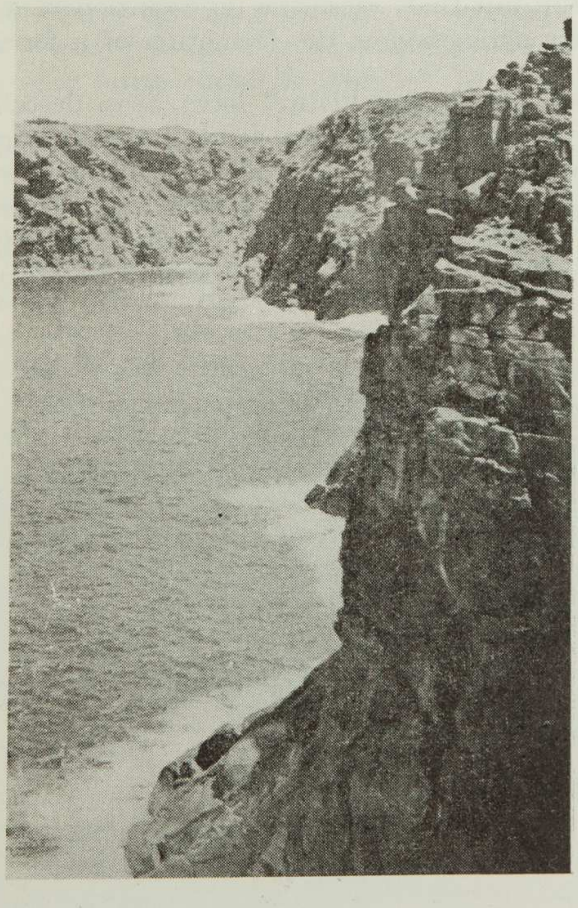
The sand-heath passes northwards into either savannah or sclerophyllous woodlands (Gardner, 1944, pp. xliv–xlvi).

* The jarrah is *Eucalyptus marginata*, the karri is *Eucalyptus diversicolor*.

C. Soils

According to Teakle (1938) the Jarrah Region part of the Strip is in the major zone of grey, yellow, and red podsolized soils. The rest forms the Eyre Soil Region in the major soil zone of red-brown earths, passing northwards, in its western half, into the Stirling Soil Region of greyish, clayey soils, and, in its eastern half, into the Fitzgerald Soil Region, which is in the major soil zone of grey and brown solonized soils.

Mr. Robert Smith, Regional Officer, Division of Soils, C.S.I.R.O., has kindly allowed us to consult, and quote from, his paper, not yet published, on the physiography and soils of the Cranbrook-Mt. Barker Area, i.e., the western end of the Strip. He states that uplands of Pre-Cambrian rocks and the " ancient alluvial fill," in places 100 feet thick, of the wide, shallow valleys, are in the main covered by " a shallow mantle of Tertiary soils which have been but little disturbed by Quaternary rejuvenation of the rivers. Only in steep, narrow valleys of such streams as the Hay, Kalgan, and Frankland is the country rock sufficiently exposed for the formation of Quaternary soils." The Tertiary soils that have been formed on the uplands are generally either a lateritic gravel mixed with sand and underlain by several feet of kaolinized bed-rock or a grey, leached sand, about 2 ft. thick, overlying a few inches of pisolitic laterite which is underlain by kaolinized bedrock ; those formed over " ancient alluvial fill " consist usually of greyish sand in the clayey subsoil



Text Fig. 3.

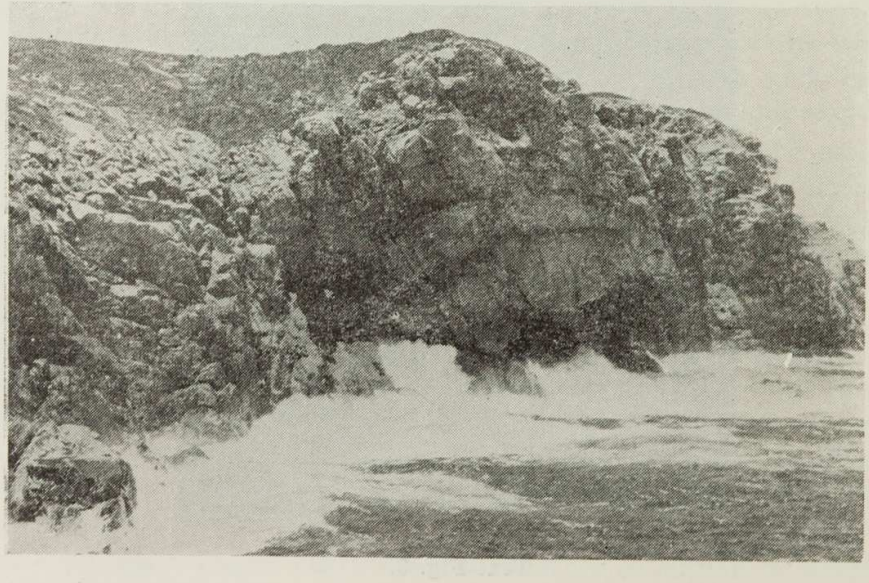
Irregular and precipitous coastline in basic sill, West Cape Howe.
H. T. Phillipps, Photo.

of which there is an accumulation of one or more of the following :—sodium chloride, iron hydroxide, and calcium sulphate. The Quaternary soils are only in the narrow valleys of the rejuvenated streams and are shallow loams which vary according to the parent rock, into which they pass gradually.

The soils of the eastern three-quarters of the Strip belong, as already noted, to Teakle's Eyre Soil Region.

Reconnaissance soil-surveys by the Soils Division C.S.I.R.O. south of the Stirling Range have reached eastwards as far as the Pallinup River, and Mr. Robert Smith has kindly allowed us to make use of his unpublished report. We learn that the soils are predominantly grey and sandy, passing down in a few inches into a yellowish, more clayey sand with a layer of ferruginous "gravel," which, we suggest, is concretionary in origin. In many places this gravel is cemented into a continuous layer of laterite. At a depth of about 5 ft. the subsoil passes either into the spongolite of the Miocene Plantagenet Beds or into deeply weathered Pre-Cambrian rocks. In some parts of the area there are however fixed dunes, and in their deep sand, there is hardly any development of the sub-surface ferruginous material. In other places again solid laterite is exposed at the surface. In the valleys that have cut down about 200 ft. to the basement of Pre-Cambrian rocks, the soils do not have more a faint trace of the laterite layer. The observations recorded by Mr. Smith seem to us to show not only that the well-developed laterite layer, at or below the surface on the plain, was formed during a former physiographic cycle (Prescott, 1931, p. 49), but that, after the intervention of a more arid cycle, the present conditions again favour the formation of a ferruginous hardpan.

The soils of the "Esperance Plain" have been described (Teakle and Southern, 1937) as typically grey siliceous sands with a ferruginous or gravelly subsoil, replaced where the sand horizon is deep, by yellowish mottled clay with soft ferruginous gravel. In the few places where erosion has removed the 30 or more feet of incoherent material, the underlying gneiss is reached, which by weathering has produced a brown earth type of soil with woodland



Text Fig. 4.

Precipitous, gneissic cliffs, Point Hood, Doubtful Island Bay.

H. T. Phillipps, Photo

vegetation quite different from the heath of the plain. Near Scaddan, about 30 miles north of Esperance, mallee soils, which are greyish, calcareous, and solonized, make their appearance. They extend over large areas to the north of the Strip (Burvill & Teakle, 1938) and are quite distinct from the grey sands of the "Esperance Plain."

There does nor seem to be any published information about the soils between Esperance and the Pallinup River, nor about the soils east of Esperance.

The soil along the Israelite Bay-Norseman track is calcareous, with much travertine. This first appears at the top of the escarpment, about 10 miles north of the coast, and covers most of the country as far north as Mt. Ragged, where it is replaced by sandplain. This continues for some distance northwards, where travertine again occurs. Much of the country east of Mt. Ragged and the Russell Range is covered with travertine, which probably extends to the Nullarbor Plain.

The underlying rocks, wherever exposed, are the same metamorphic and igneous types as those to the west, where we did not find any development of travertine, and, in the vicinity of Mt. Ragged and the Russell Range, consist of quartzites and micaceous schists. It appears probable that the travertine has originated from calcareous dust, derived from the Nullarbor Plain during a more arid period.

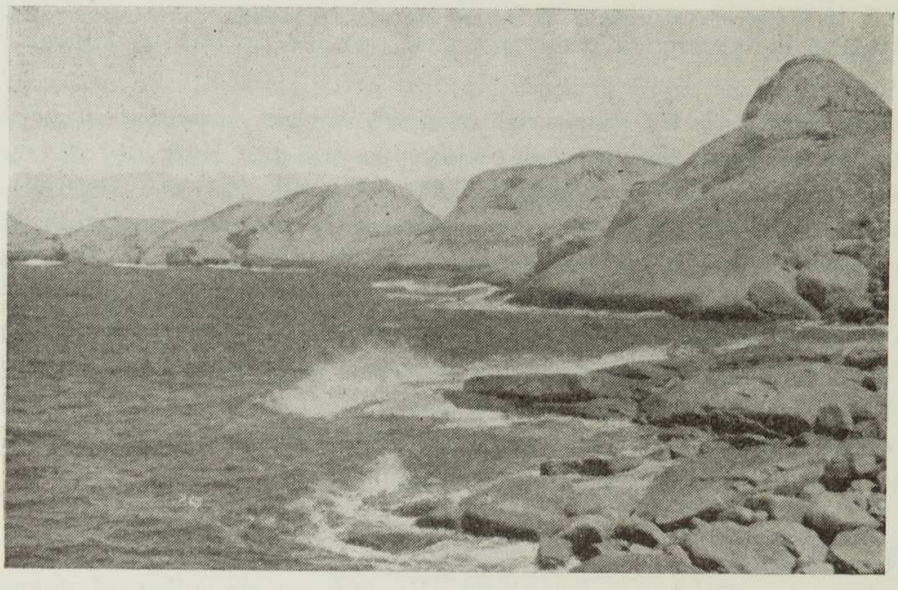
This country carries very dense scrub. When Roe crossed it in November, 1848, he wrote that the "saplings" 12 or 15 feet high were "so densely packed that only axes could have opened a passage"; even the "scrubs of a more yielding character" were "frequently so dense that at a distance of three or four feet no part of a horse could be seen."

D. Coast.

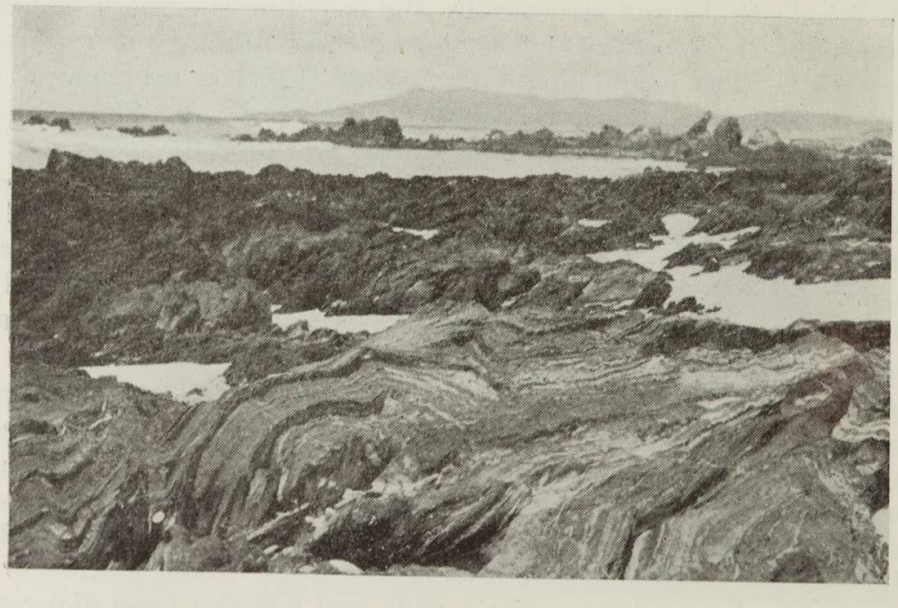
1. *General.*—We have examined the 600 or so miles of coastline at fairly close intervals, except between Hopetoun and Esperance, confining our attention to the rocky parts, which have a total length considerably greater than have the intervening sandy beaches. If the rocks are fairly uniform both lithologically and structurally the coastline is smooth in plan and regular in profile, the reverse being the case where lithology or structure, or both, are varied. The neighbourhood of Point Hillier is an example of the first type; its cliffs rise almost vertically from near the shoreline to a height of 200 feet or more and form a nearly straight coastline for five miles. This and other stretches of uniform, rock-bound coastline in this part of the Strip are in Coastal Limestone, which is Pleistocene in age and is, in a broad sense, horizontally bedded, though, in detail, cross-bedded. Other less striking examples, formed in horizontal Miocene sandstones and shales of the Plantagenet Beds, were noted at Dillon Bay, and, running north for apparently about three miles, along the shore of Cheyne Bay.

Irregular, rocky coastlines are much commoner. They are carved out of metamorphic and igneous Pre-Cambrian rocks (text figs. 3–5). Jaggedness in plan large enough to show on a mile-to-the-inch map is mainly due to marine erosion acting along joints, but we have seen one impressive example due to a basic intrusion which is, owing to its structure, more susceptible to mechanical erosion than the surrounding rock; this is near Point Hood, where the waves have excavated a chasm about a chain wide and 200 feet deep along a basic dyke, and have, moreover, apparently tunnelled at sea-level along the dyke beyond the end of the chasm and then, as miners would say, have "risen"

about 200 feet to form a small "blowhole" several chains inland from the edge of the cliff. Again, at the cape on the south side of Duke of Orleans Bay there is a striking piece of coastal scenery, of which text fig 5 is a distant view. The contorted gneiss has strong joints trending N.N.W. and dipping east at 60°, and also has almost horizontal joints, but the jointing hardly explains the carving of the rock into several great rounded buttresses, and the presence on the south side of the biggest buttress of a corrie-like excavation facing the sea—though indeed one of its walls is a joint-face. Nowhere else along the coast have wee seen sculpturing like this, and closer examination may show, as it may also for the caves, etc., near Cape Le Grand which are described later, that the forms developed are due to unusual structures and other features in the gneiss.



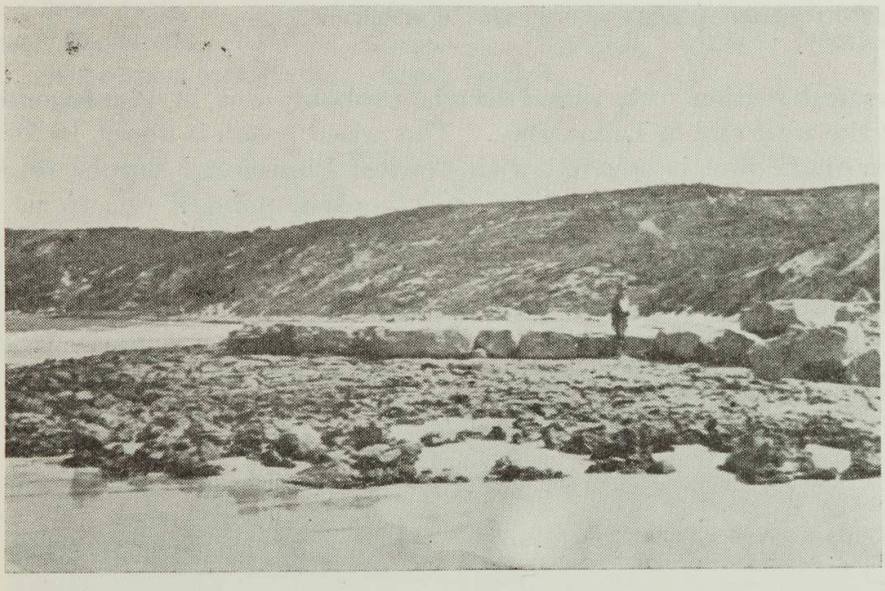
Text Fig. 5.
Rounded buttresses of contorted gneiss, Duke of Orleans Bay.
H. T. Phillipps, Photo.



Text Fig. 6.
Wave-cut platform in folded quartzites and schists near the mouth of the Hamersley River.
H. T. Phillipps, Photo.

2. *Rock Platforms.*—Platforms, seldom awash in summer when we saw them, but doubtless wave-swept in winter storms, are noticeable wherever the Pre-Cambrian rocks are traversed by strong, nearly horizontal joints. In most places they are only a few yards wide, but there is a platform five chains or more across, in much folded quartzites and schists, near the mouth of the Hamersley River (text fig. 6), and the outer 15 chains of Point Malcolm (composed of gneiss) is a flat tongue within reach of storm waves.

Platforms in horizontally bedded calcareous sandstones, at, or a few feet above, sea level occur at Pt. Irby, Doubtful Island Bay, and east of the mouth of Hamersley Inlet and in many other places. At Pt. Irby the platform is about half-a-mile long and a chain or so wide (text fig. 7). A smaller platform of sandstone, lying on the " old rocks " occurs near the mouth of Hamersley Inlet. At the south end of Doubtful Island Bay, at the time of our visit, a sandstone breakwater about half-a-mile long, over which the waves were breaking, lay parallel to the shore, so that there was a strip of quiet water about a chain wide along the sandy beach.



Text Fig. 7.

Platform of cross-bedded sandstone, underlain by very coarse conglomerate, near Point Irby.

H. T. Phillipps, Photo.

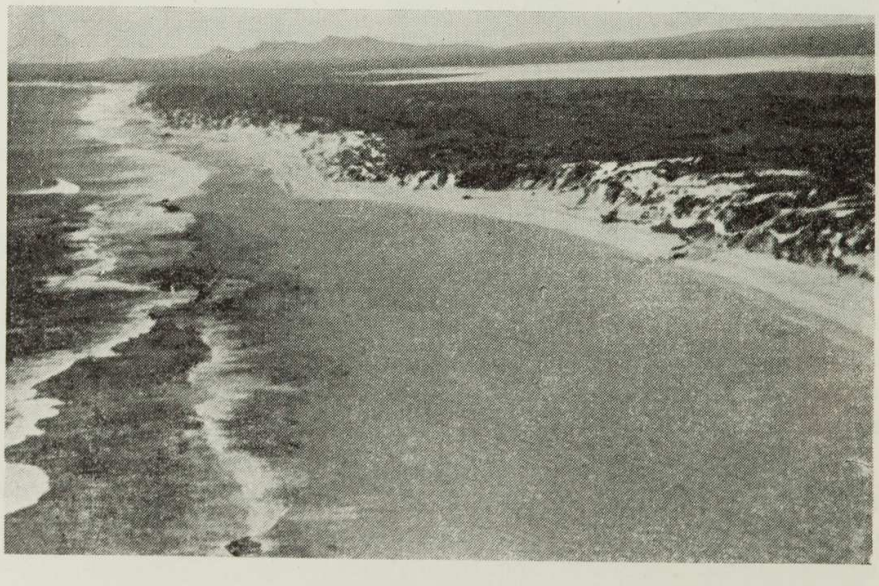
Similar breakwaters occur parallel to Second, Third, Fourth and Eleven-mile Beaches, situated west of Dempster Head, and south of Esperance. The west end of the reef at Third Beach contains numerous waterworn pebbles of granite, evidently derived from the adjoining outcrop. The presence of these pebbles and fragments of recent shells suggests that the breakwaters are consolidated beach sand.

Dr. D. L. Serventy informs us that a similar breakwater, about three miles long, fringes the beach a little east of Hopetoun (fig 8) and is of considerable importance in connection with the salmon-fishing industry. Roe, on January 1, 1849, recorded the occurrence near " Flat " or " Smooth " Rocks, a few miles west of C. Knob, of a " ledge of flat rocks even with the water's edge, inside which was a sheltered space 20 to 60 yards wide and six to 10 feet deep." This was probably similar to the " breakwater " at Doubtful Island Bay.

These platforms and breakwaters of sandstone have probably been formed by the cementation of beach sands (Kuenen, 1950, p. 432). The precipitation of $CaCO_3$ in the sea, especially where it is broken by surf, has been explained by Fairbridge (1948, p. 26). Higher-level shelves, floored with metamorphic or igneous rocks and bordering on the coastline, were noticed in many places, *e.g.*, near Long Point, Cape Knob, and (from a considerable distance) on some of the islands. Much more impressive platforms, sloping towards the coastline at about 5°, and in places probably more than half-a-mile wide, occur about 250 feet above sea-level almost continuously for about ten miles on the sea side of Middle and East Barrens (fig. 9), and of West Mt. Barren. They are cut in metamorphic rocks and are trenched by small watercourses which drain the steep slopes of the hills. The gullies which we observed entered the sea at grade so that, where crossing the platform, they are 200 feet or more deep.

3. *Raised beaches and sea-built flats*—Flat areas a few feet above sea-level, of loose or slightly compacted sand, clay, and shells, in some places with considerable amounts of carbonaceous material, border parts of most inlets and occur in other places along the coastline.

A natural section of a raised beach, probably cut in Plantagenet Beds, occurs at the west end of Dillon Bay. The raised beach is about 10 feet above high-water mark and is covered with Coastal Limestone, slipped down from higher levels. A somewhat similar raised beach, pointed out to us by Mr. V. Serventy, occurs near the west end of West Beach (Esperance). It is about 10 feet above high-water mark, is from one to two feet in thickness, and is composed almost entirely of recent shells and shell fragments, including a number of *Patellas*, some of which still retain their original colour. Underlying it is aeolianite containing shells of the land-snail *Bothriembryon* a variety of which still lives on the sandhills above.



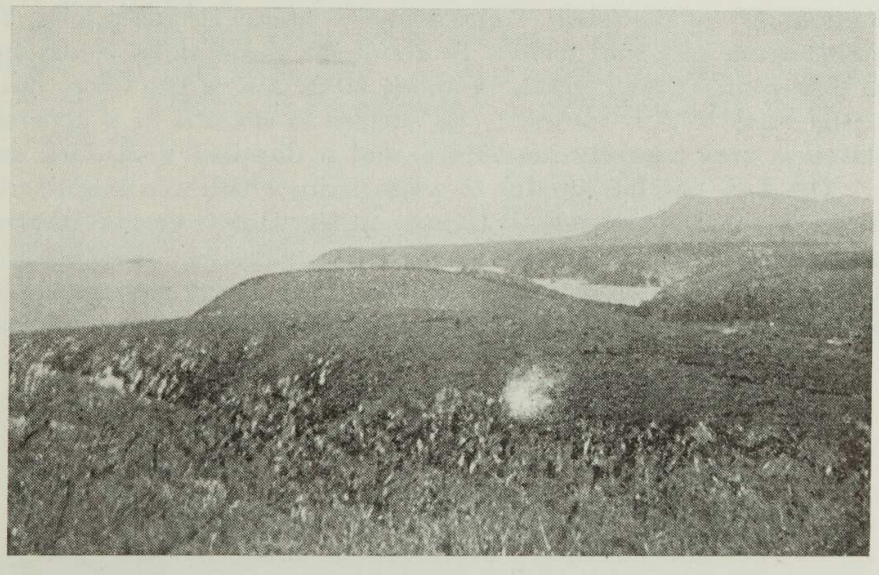
Text Fig. 8.

Sandstone "breakwater" fringing the coast a little east of Hopetoun.

D. L. Serventy, Photo.

The flat at the mouth of the Thomas River is only a few feet above high-water mark and carries a layer of marine shells in which *Anadara trapezia* is very abundant. At Cheyne Beach, 10 feet or perhaps more above high-water mark, Blatchford (1927) found quantities of shells similar to those in raised beaches near Perth.

A large flat about 20 feet above the sea lies between Point Malcolm and Israelite Bay and extends inland as much as five miles. In its S.W. part are claypans, bordered in many places by vertical banks, two or three feet high, of limestone largely composed of *Coxiella striatula.** This limestone also forms isolated "mushroom rocks" rising two or three feet above the surface of the claypan, on which *Anadara trapezia* and other marine shells are scattered. The greater part of the area is however a salt mudflat, at times covered with water and marked " Lagoon " on the maps. This lagoon is about five miles long from N.E. to S.W. The track from Point Malcolm to Israelite Bay skirts its S.E. side and is separated from the sea by a narrow belt of partly fixed dunes. In places near the track the flat is covered with many marine shells most prominent among which are* :—*Cardium racketti, Anadara trapezia, Ostrea sinuata, Katelysia scalarina,*— very abundant and very large specimens—*Cominella eburnea, Cominella lineolata, Niotha pyrrhus, Uber conicum, Parcanassa pauperata, Akera bicincta.*



Text Fig. 9.

Wave-cut platforms in metamorphic rocks, about 250 feet above sea level, on the south side of Middle Mount Barren Range.

H. T. Phillipps, Photo.

On the inland side of Point Dempster (Israelite Bay) waterworn boulders and pebbles of gneiss are scattered over flattened surfaces of the same rock, at heights varying from 40 to 60 feet above the sea.

Progradation is shown by :—Grassmere Valley (Jutson & Simpson, 1917, p. 56), a former strait between Princess Royal Harbour and Torbay Inlet, the tied island in Duke of Orleans Bay, at the mouth of Princess Royal

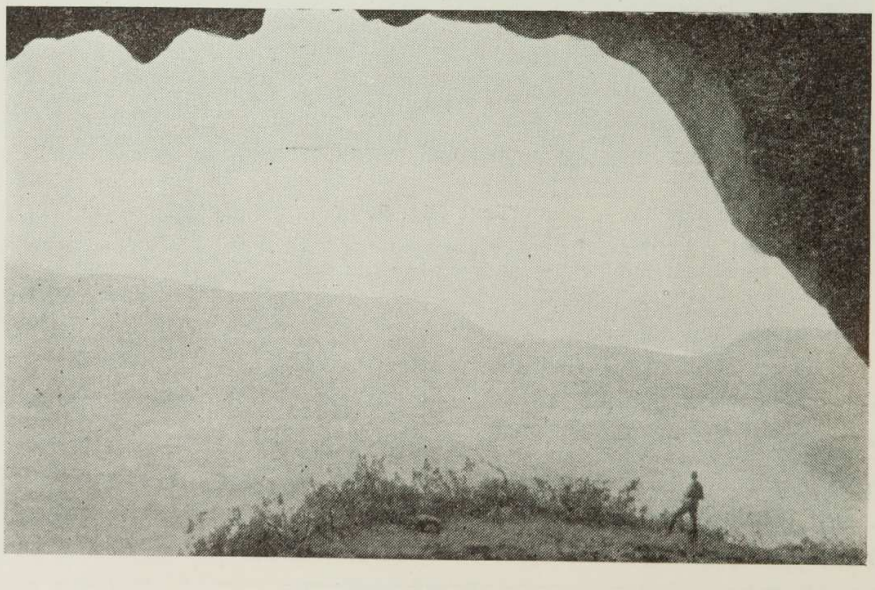
* Identifications very kindly made by Mr. B. C. Cotton (1951), Conchologist, The South Australian Museum, who notes in a paper now in the press that these shells are " remarkable in that they are frequently comparatively large, suggesting that conditions . . . . . were more congenial than those under which the same species live today. This stranded beach deposit is almost certainly contemporary with the well-known 15-20 ft. eustatic beach developed around the coast of Southern Australia."

Harbour, and according to local information, the tip of Point Dempster, which in the " early days " was separated from the mainland by a passage through which whaleboats could pass, but which is now filled with sand.

Miss Dirksey Cowan has kindly drawn our attention to another instance of progradation on the south coast, which certainly deserves mention, although it is far east of the part which we are describing. The schooner " Bunyip " was wrecked probably in 1876—at latest in 1878—near Twilight Cove, which is nearly 170 miles N.E. of Israelite Bay. In 1900 the hull was 200 yards inland and " separated (from the sea) by sandhills 8 ft. to 10 ft. high with saltbush."

4. *Caves.*—On the south side of Duke of Orleans Bay in a rather sheltered, north-facing position, is a wedge-shaped cavity 40 yards in length and 5 ft. high in front, its ceiling gradually sloping downwards to the floor for about 20 yards. Its floor is a joint in the gneiss which dips N.E. at 15° and is smooth and devoid of rubble, being within reach of storm waves. The roof shows shallow pits and very pronounced flaking, but has no " case-hardened " lip such as overhangs the entrance of some caves at higher levels which, although not coastal features, may be conveniently discussed here.

Frenchman Peak is an isolated hill of gneiss, 858 ft. high, which rises steeply for about 600 ft. above the surrounding plain country. The hill is pierced from north to south, about 100 ft. below the top, by a tunnel sloping down at about 10° to the south. The tunnel is about 50 yards long, 25 yards across at its north end, and widens to about 60 yards at its south end (text fig. 10). The roof, at its highest, is about 60 ft. above the floor, but curves down at the sides to 6 ft. or less ; its surface is smooth in a general sense, but in detail is very coarsely mamillate, and is dappled with dark and light patches. The dark patches are due to a thin skin, which was examined by Mr. G. G. Smith of the Department of Botany in the University of Western Australia, who tells us that it is formed by a microscopic alga. The white patches mark the places from which flakes of the dark-skinned rock have recently fallen. The floor is parallel to strong, S.E. dipping joints in the gneiss and is covered



Text Fig. 10.

Southern end of tunnel through Frenchman Peak.

H. T. Phillipps, Photo.

with dust and small fragments and flakes of gneiss—except near the north end, where it is strewn with large blocks of gneiss. On the west side is a platform, perhaps 2 or 3 ft. above the floor and several yards wide, along a joint parallel to the floor. There is no evidence of water-seepage in the tunnel, nor of its being frequented by any animals, and, although it must be a veritable funnel to catch the S.W. gales, the quantity of dust, etc., on the floor shows that the winds have little if any transporting effect. The tunnel is about the same height above the sea as the possibly wave-cut shelves on Mt. Ragged and the Russell Range, 80 miles to the E.N.E., which are mentioned later, but we did not notice any sign of wave-cut shelves on Frenchman Peak or the neighbouring hills.

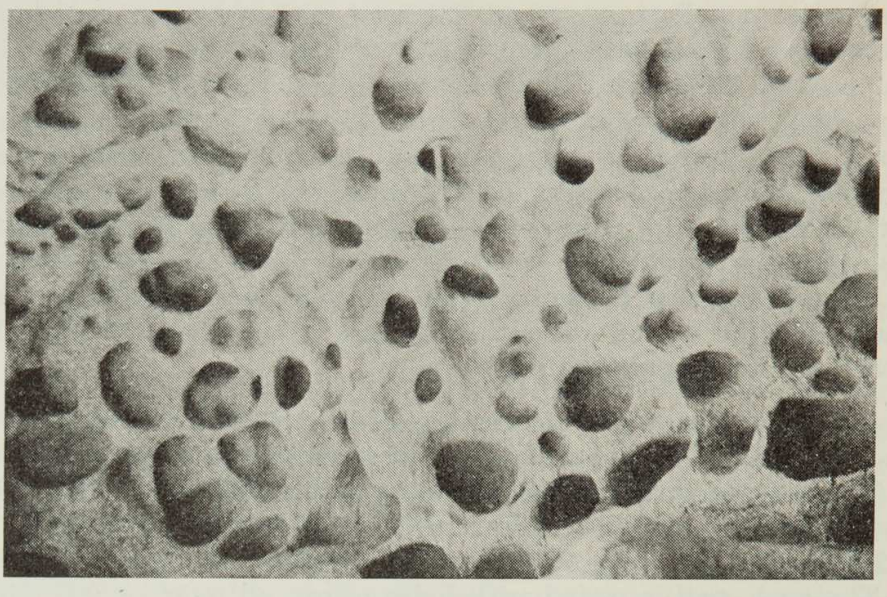
On the north side of Mt. Le Grand we examined three caves (text fig. 11) between 500 and 600 ft. above the sea, in gneiss, with varying jointing, etc. "No. 1" cave is about 20 ft. wide and deep and its front is overhung by a lip of "case-hardened" gneiss (Clarke, Prider & Teichert, 1948, p. 47). The front, 12 to 15 ft. high, is much protected from the wind by a thick growth of scrub. The back wall is pitted with holes nearly all more or less circular in cross-section (text fig. 12). They average about nine inches in diameter; their depth is not recorded but, from memory, it is about the same as their diameter; some are nearly two feet across, but the bottom of such a large hole is usually pitted with small ones. Every hole decreases in diameter inwards and is rounded at its base. The holes slope down towards the front of the cave. In the roof there are a few holes, shallower than those in the wall, but the outer part of the roof has none, and here alone is there much evidence of scaling. Unlike the Frenchman Peak tunnel, the Mt. Le Grand caves have no algal crust.

Text Fig. 11.

North side of Cape Le Grand, showing arched caves.

H. T. Phillipps, Photo.

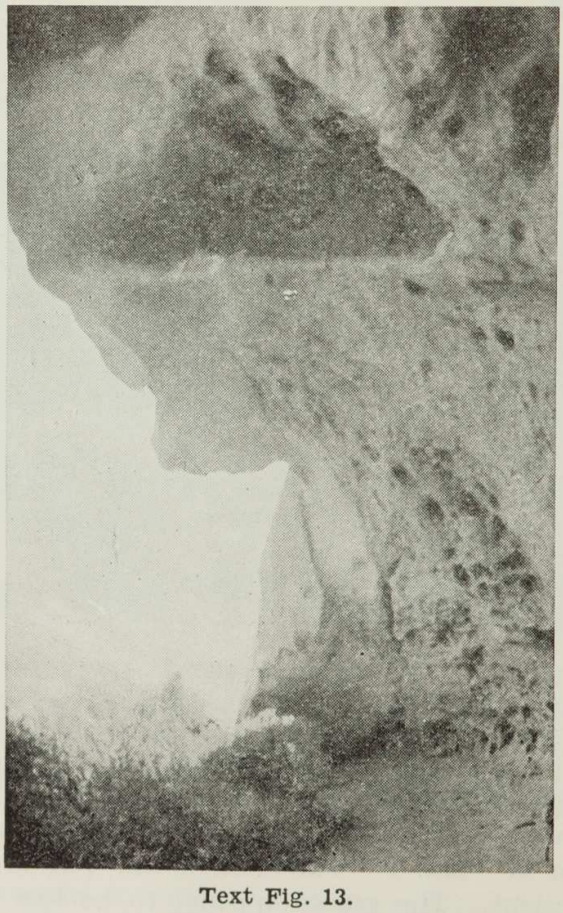
"No. 2" cave is 55 yards across the front, 15 yards in greatest depth, and 30 feet in greatest height. Pitting on its back wall is much less regular and abundant than in "No. 1" but some of the pits are much larger and flaking is more evident. The gneiss appears to be less homogeneous than in "No. 1" and is irregularly seamed with pegmatite.



Text Fig. 12.

Pitted surface inside cave in gneiss, Cape Le Grand.
H. T. Phillipps, Photo.

"No. 3" is 145 yards across the front, is 20 to 30 yards deep and its maximum height is about 60 ft. (text fig. 13). The primary holes in the back wall are as much as 3 ft. in diameter and in depth, are irregular in cross-section, and enclose many secondary holes.

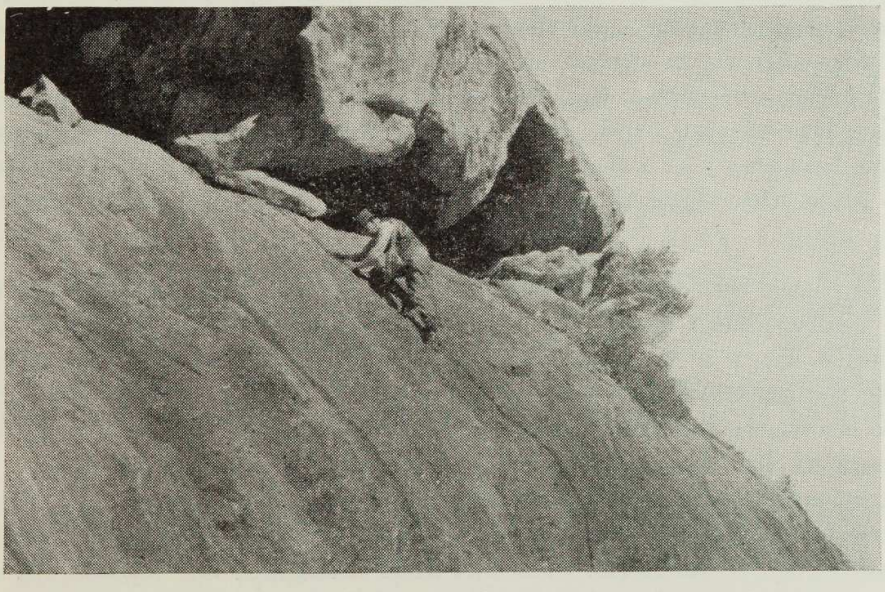


Text Fig. 13.

Cave No. 3 in gneiss, Cape Le Grand.
H. T. Phillipps, Photo.

The roofs of Nos. 2 and 3 were inaccessible. None of the three showed any evidence of wind action or of the presence of animals.

Some long, low caves, resembling that at the sea's edge in Duke of Orleans Bay, occur in a low cliff of gneiss near the house, about two miles north of the top of Mt. Le Grand. They are only 40 or 50 ft. above the sea, and separated from it by about three-quarters of a mile of swampy and sandy ground. Immediately behind the house the cliff faces S.E. and in it, about 30 ft. above the base, is a cavity, perhaps 50 yds. long, 10 yds. deep, and 10 ft. or less high (text fig. 14). The floor and roof are uneven, but, in parts of the roof there is widely spaced pitting, rather like that in the Cape Le Grand Caves, also there is the same overhanging (and incurved) lip. The cave follows joints which dip N.W. at about 20°. About 5 chains farther north the cliff swings to face S.W. and along this face there is a cave about 20 yds. long with a very pronounced overhanging lip. The roof is flaky and varies in height from 4 to 12 ft., the lower parts being in more quartzose phases of the gneiss. The cave seems to have formed along a joint and continues inwards, another 10 yds. or so, as a crack about 1 ft. wide along a parallel joint.



Text Fig. 14.

Cave in gneiss, about two miles north of Cape Le Grand, showing overhanging and incurved lip.

H. T. Phillipps, Photo.

Caves similar in shape to those in Mt. Le Grand occur on Dempster's Head (Esperance) and about a quarter of a mile west of Duke of Orleans Bay. Both these caves face west and are about 100 ft. above sea level. No pits were noted in their roofs and the gneiss appeared to have been removed in small flakes about $1\frac{1}{2}$ inches in diameter and one-eighth in. thick. A somewhat similar concave type of weathering was seen in many large boulders of granite near Fourth Beach, Esperance.

No satisfactory explanation of the mode of origin of these caves has occurred to us, though some may no doubt be explained by the granular disintegration of the gneiss inside an indurated veneer, which has either been broken, or chemically destroyed by patches of vegetation, especially lichen

or moss, growing on the gneiss (White, 1944). Perhaps the four last described are due partly to marine corrosion, when sea-level was relatively about 80 ft. higher than now ; just as present-day wave action is partly responsible for the low-roofed cave at Duke of Orleans Bay. The Frenchman Peak tunnel may have been formed in the same way and record a time when sea-level was relatively several hundred feet higher. The high-arched caves on Mt. Le Grand may have originated quite independently of sea-action though it is noticeable that all those we have seen are at about the same level.

It was noticed that, on the side of Frenchman Peak, and also perhaps on Mt. Merivale (seen from a distance only) there is a tendency to the development of small, steep-sided recesses which might be likened to miniature cirques. These may possibly be the beginnings of caves of the high-arched type. Structure and lithology may play a part here, as suggested above for the corrie and buttresses near Duke of Orleans Bay.

5. *Beaches and Dunes.*—White sandy beaches form wide open bays between the rocky parts of the coastline. Behind them there is generally a belt of moving sandhills, which is seldom more than a few hundred yards wide, although in some places there are sand-drifts covering hundreds of acres, and steadily advancing inland. At the mouth of Dempster Inlet wind-driven sand thinly covers an uneven surface of schist and quartzite, and, from a distance, looks like a dune of rather unusual size and abruptness. The beaches rarely have exposures of the " old rocks " which were our main concern, and are tedious to traverse. We therefore avoided them, where possible, and have probably thus missed much information about raised beaches and progradation.

Dunes, fixed by scrub, and standing on ground at about the 20 ft. level, occur in many places along the coast, particularly between Point Malcolm and Israelite Bay, and near Esperance. Fixed dunes are also developed just inside the coastline at higher levels ; thus on the west side of Dillon Bay, near Cape Knob, the land rises very steeply from the coastline to 400 ft. or more, and is capped by fixed dunes, which overlie Coastal Limestone. Similar high ground a few miles west of Cape Knob carries fixed sandhills, which here also probably overlie Coastal Limestone. On West Cape Howe Promontory the metamorphic rocks north of a flat area underlain by a basic sill are, for some distance, covered by about a hundred feet of partly consolidated sand which seems to be interbedded with Coastal Limestone. This sand is fixed by heathy vegetation and is arranged in east-west ridges. The country N.W. to N.E. of Knapp Head has the same topography. Again, in similar surroundings just east of Point Nuyts, at heights of over 300 ft. above the sea, a similar terrain carries the small, permanent, freshwater Crystal Lake—the only one of its kind that we have seen in the Strip.

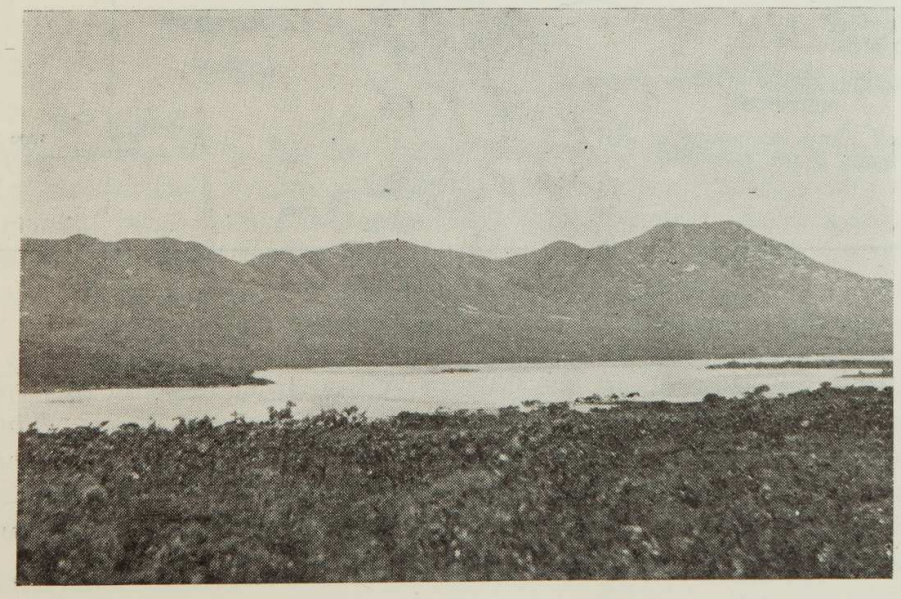
We unfortunately made no systematic notes on the character of the sands composing the beaches and dunes.

6. *Springs.*—These occur at many places along the coastline at contacts of Coastal Limestone or of unconsolidated sand with Pre-Cambrian rock. The largest that we have seen is on West Cape Howe Promontory, nearly a mile N.N.W. of the cape, close to the beach, at the contact between the fixed sand and the old rocks. At least four other large springs at similar contacts occur between Point Nuyts and the mouth of Nornalup Inlet. These are actively sapping back in the unconsolidated sand to produce very steep-sided

gullies, in one of which, heading near Crystal Lake and flowing north into Deep River, large karri trees grow, their leafy crowns rising above the brink of the gully, so that, from a little distance to the west, they look like a line of small trees growing on the undulating moor.

7. *Inlets.*—" Inlet " appears often on maps of the south cost of Western Australia but has hardly the meaning of a " small arm of the sea," just as the many " lakes " in the interior of the State are not lakes in the generally accepted sense. There are about twenty " inlets," large and small, in the Strip. One, Waychinicup, is completely rockbound, except for a narrow opening ; the rest are partly or completely closed by sand-bars, which have driven the actual or potential mouth eastwards in some, westwards in others, but at the Gordon Inlet, at the mouth of the Gairdner River, appear to have closed the mouth from both directions. These differences are doubtless due to local currents, mentioned in a previous section.

Only four inlets can be said to be " permanently " open to the sea ; of the rest, some are known to have been open at times in the last hundred years, of others there is no record. On a map the inlets have the outline of drowned valleys, but, so far as we know, they are flat-floored, the slopes of the surrounding hills not being continued under the water which covers some of them. We have already, in discussing the sea floor, noted that the King-Kalgan Inlet (Oyster Harbour) is the only one from which a continuation across the continental shelf has been traced—though other submerged channels may be detected when many more soundings are available. A few inlets are always covered with water ; most are boggy flats with a crust of " salt " (mainly sodium chloride) (text figs. 2, 15), but having in places a very shallow sheet, or just a film, of very saline water. No defined channel across any of these flats is noticeable. In March, 1949, Mr. H. A. Ellis (Government Geologist), pointed out that there was then a constant strong " spring " of sea-water at the foot of the dune which separates Culham Inlet from the ocean, so that, at that time, the surface of the inlet was below sea-level ; on the other hand,

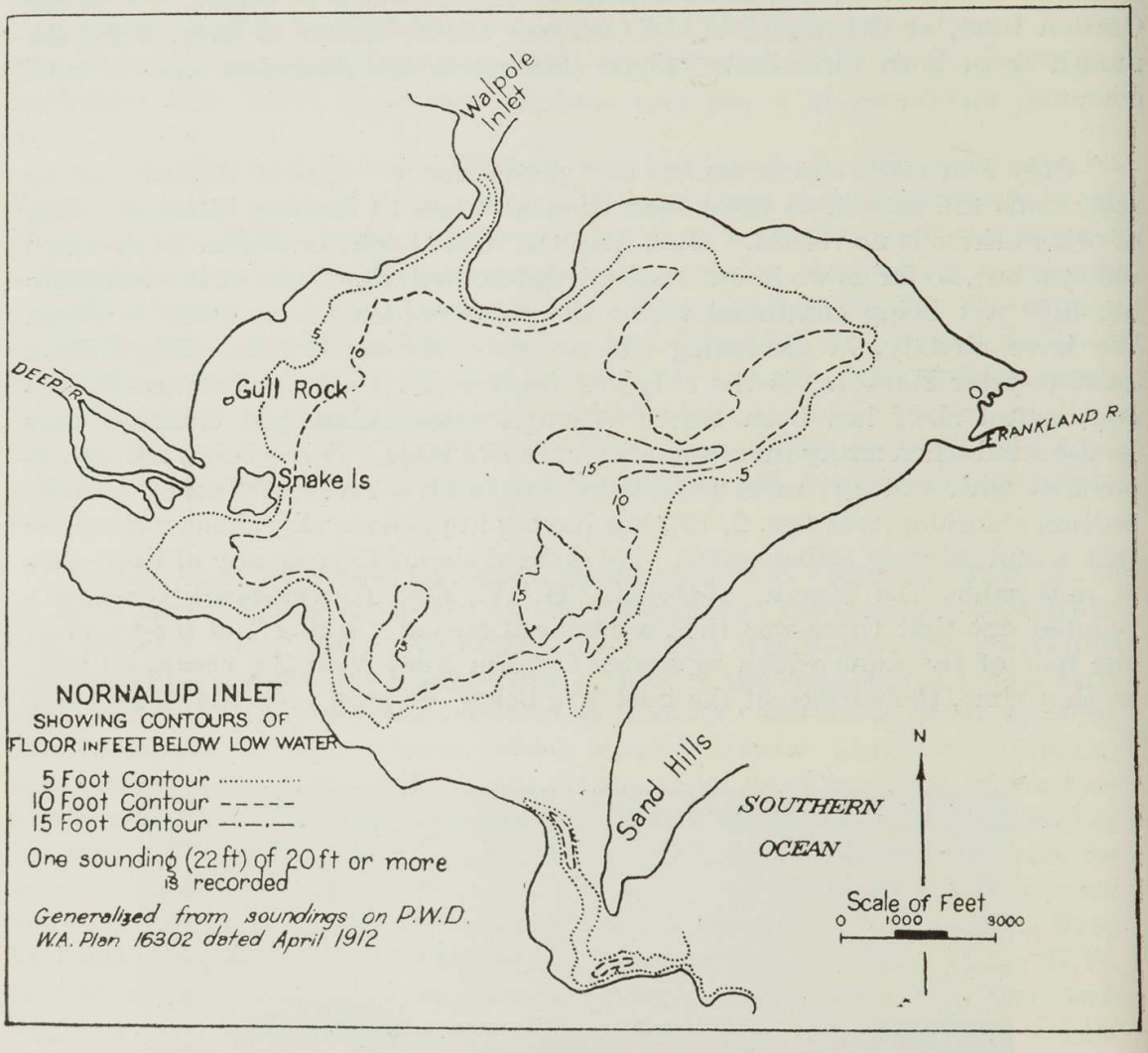


Text Fig. 15.

Middle Mount Barren and Dempster's Inlet.
H. T. Phillipps, Photo.

a century before, in April, 1849, A. C. Gregory recorded that after heavy rains the water in Culham Inlet had risen 7 ft. above its " usual level " when it broke through the bar, and for three days the outflow was too strong for his horses to cross the mouth by swimming.

The only complete information as to the floor of a permanently water-covered inlet is given by a detailed plan of the soundings in Nornalup, which was made nearly 40 years ago and from which, by kind permission of the Under Secretary of the Public Works Department, we have compiled text fig. 16. This shows that the floor of the inlet is almost as flat as that of an inlet now reduced to a mud flat.



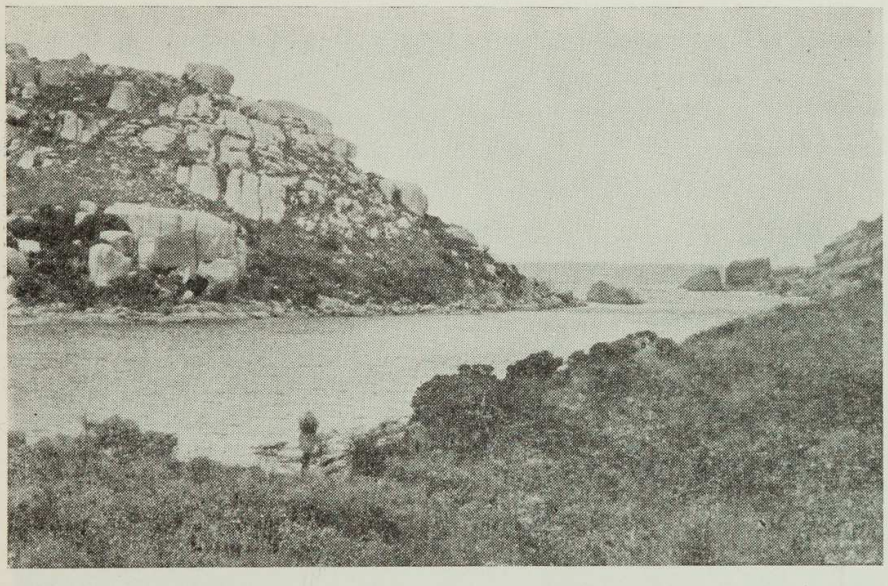
Text Fig. 16.

Nornalup Inlet.

A little information about the floor of Wilson Inlet is given by a plan of soundings, made in 1919, near the mouth of the Denmark River. The inlet is 6 ft. deep or more where the river enters it, but at 100 ft. out from the river mouth the water shoals to 2 ft. or less, and this shallow water persists for 1,200 ft. in a S.E. direction. Beyond that no soundings are shown but it is noted that the water " deepens towards the ocean bar."

Material brought in by occasional floods and by wind has probably obliterated the channels both on the water-covered and on the mud-covered inlets.

Waychinicup (text fig. 17), on the east side of Mt. Manypeak, is the only inlet without a sand-bar that we have seen on this coast. It is at the end of a rather wide, rocky valley through which flows a perennial stream. Capt. Pedersen and Mr. N. E. Stewart of the C.S.I.R.O. Fisheries Research Vessel "Warreen," have, through Dr. D. L. Serventy, very kindly supplied the following particulars regarding this inlet :—It has a steep-sided entrance, about 80 yards wide, without a bar, and is an excellent harbour for boats up to 40 feet long, although, with an onshore wind or unusually heavy swell, there would be broken or confused seas in the entrance owing to its narrowness. Just inside the entrance the inlet turns sharply to the east and is completely protected from every quarter. The inner part is only deep enough for rowing boats (having been no doubt silted up by the creek) but the outer part is fully 12 feet deep and measures about 300 by 300 yards.



Text Fig. 17.

Waychinicup Inlet.

H. T. Phillipps, Photo.

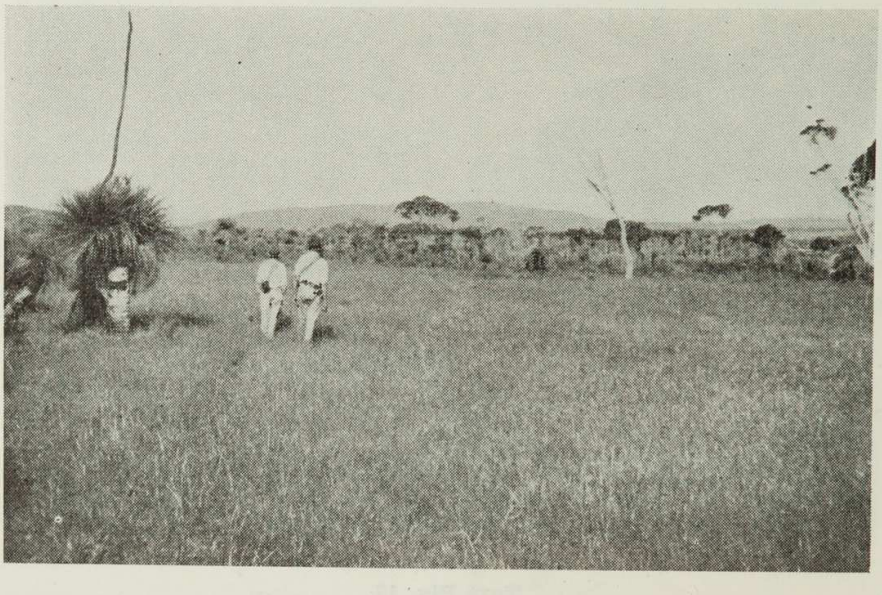
There appear to be but few inlets between Hopetoun and Esperence—a part of the coast that we have not seen—but, judging from the map, there are many coastal lakes, such as Jerdacuttup and Shaster, which are near, but perhaps not connected with river mouths. Possibly field-work will show that these lakes were once part of inlets at the mouths of the rivers and have been cut off by drifting sand. The relative absence of inlets in the eastern part of the Strip would thus be due to the weakness of the rivers ; however, such coastal lakes as the "salt lagoon" at Israelite Bay, and Grassmere, about 10 miles west of Albany (Jutson & Simpson, 1917, pp. 56, 58) were probably formed by progradation.

E. Hinterland.

1. *General.*—The part of the Strip that lies west of a line running about north from Albany differs from the rest, as already noticed, in vegetation and soils : the two parts differ also topographically.

Mr. Robert Smith, to whose work on the soils we have already referred, has kindly allowed us to make use of his unpublished account of the physiography of the western end of the Strip, and of the eastern part as far as the Pallinup River. We hope that we have not mis-represented Mr. Smith's views in combining our observations with his.

2. *Jarrah Region Part.*—This is an undulating, forested plateau which rises above 1,000 feet only in isolated hills, such as Mt. Lindesay and Warriup Hill.* This type of country persists southwards to within 10 miles or less of the coastline, which has already been discussed. In some places indeed the hilly country, only exceptionally rising above 500 feet, extends to the coastline, but the coastal fringe of high land is in most places separated from the hinterland by a low-lying strip of swampy or sandy ground, *e.g.*, between Torbay Inlet and Princess Royal Harbour (Clarke, Prider, and Teichert, 1948, pp. 112–3) and near Long Point (text fig. 18).



Text Fig. 18.

Swampy coastal country east of Warriup Station.
J. Clarke, Photo.

The plateau averages 800 to 900 feet above sea-level. The valleys, which cross it, vary from juvenile to senile. The Frankland, Deep, Hay, Denmark, and Kalgan Rivers are juvenile, and the last three are cutting back into the senile Upper Kent River. The Kent is juvenile in its lower, southern part, senile in its upper, northern part, where it is more or less connected with a series of shallow lakes and swamps, of which Lake Matilda is one, trending east and west. There is a similar east-west-trending series of lakes and swamps in the vicinity of Lake Muir. The Gordon, which joins the upper Frankland, is a senile east-west river.

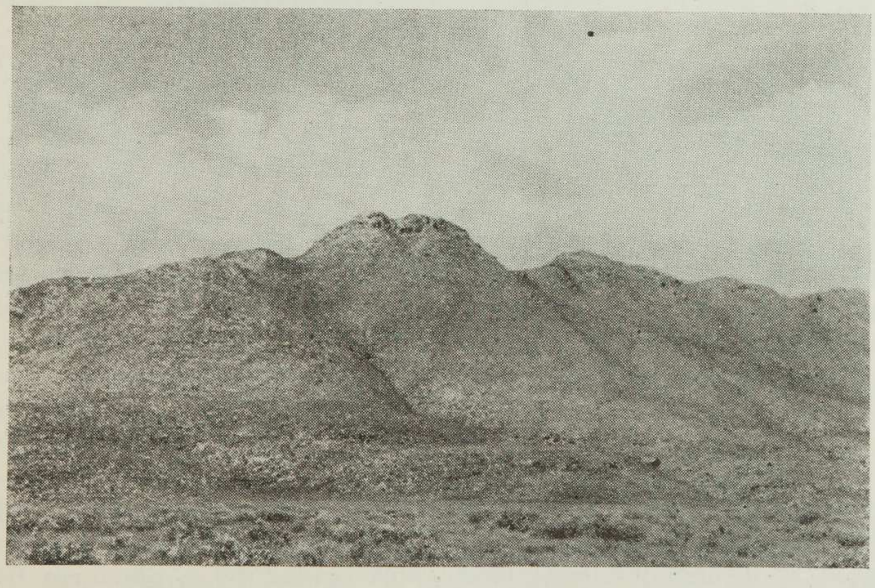
There are thus, in this part, valleys of two types—an older east-west system and a younger north-south. The older is now a belt, 30 miles or so wide, of almost level country on which are many swamps and shallow lakes. It drains westward from near the Perth-Albany railway line, at least as far as

* There are two hills called " Warriup " in the Strip—that mentioned here is about 8 miles west of Cranbrook, the other is near the coast, about 43 miles N.E. of Albany.

Lake Muir, and is crossed by the juvenile Frankland, and partly crossed by the Deep, whose head is cutting back towards Lake Muir. Drainage along this belt has been partly blocked, during a former more arid cycle, by wind-blown material, thus leading to the formation of swamps and lakes, many of which are connected at times. It is noticeable that soluble salts are more concentrated in the lower, western, parts of the system so that freshwater swamps may occur on the higher ground, brackish or salt-water on the lower.

Here then are the same two types of valley as near the west coast, east of the Darling Scarp (Jutson, 1934, p. 171) but there the north-south valleys are the older, and here there is no structure comparable to the Darling Scarp.

3. *Stirling Region Part.*—This, broadly speaking, is a plain, between 200 and 700 feet above sea-level, above which stand many isolated hills. Near Ravensthorpe, however, a belt* about 30 miles wide, of greenstone country crosses this plain and reaches within about 25 miles of the coast. Woodward (1909 (b), pp. 7–9) writes that this belt is dominated by the Ravensthorpe Range, which runs N.W. from Kundip, and is more conspicuous from the lower country to the S.W. than from the N.E. " where the adjoining plains are more elevated." In detail, as described by Woodward and illustrated by H.W.B. Talbot's contour map in the same bulletin, the topography of the Ravensthorpe belt resembles that of the " greenstone belts " of the Kalgoorlie Region to the north, and is quite unlike that of the Stirling Region, and will not be further discussed here.



Text Fig. 19.

Mount Ragged from the north.

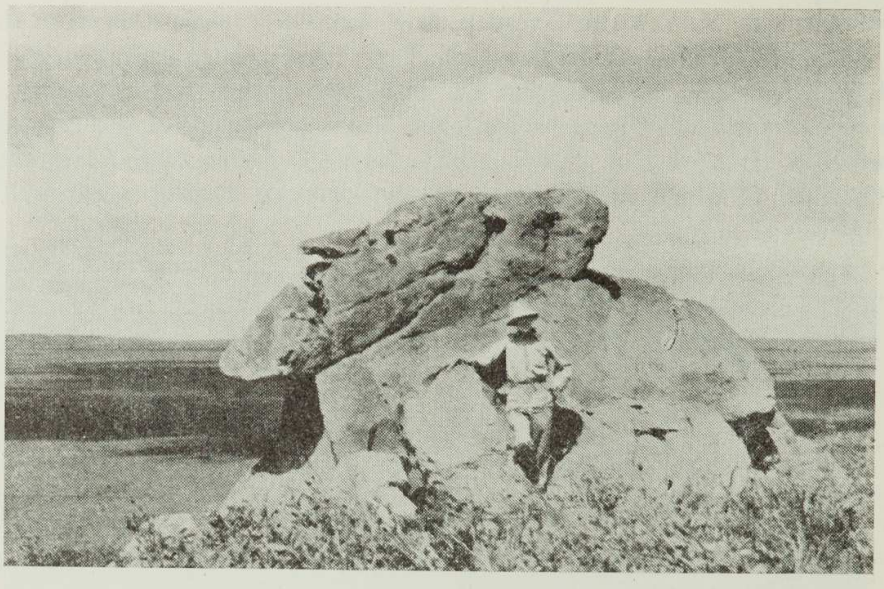
H. T. Phillipps, Photo.

(a) Plain.—The plain, but for the interruption of the Ravensthorpe belt, stretches from near the Perth-Albany railway to Cape Arid. It is, quite apart from the many valleys which cross it, not all at one level as the word " plain " might imply, and what little evidence there is indicates that it slopes down very gently to the south. There is also some indication that, coming south, there is a break of some abruptness between the 400 and the 200 feet levels, but this is largely only an " impression " supported to some extent by aneroid readings.

* Part of the Kalgoorlie Region, the boundaries of which as shown by Clarke (1936, p. xii.) needs much alteration.

The only accurate levelling across the Strip (*i.e.*, from north to south) is along the Perth-Albany, Ravensthorpe-Hopetoun, and Coolgardie-Esperance railways. The country near the Perth-Albany line is dotted with isolated hills, and slopes down very gently (at less than 1 in 400) southwards till within 10 miles of the sea, where the slope steepens to about 1 in 95, until it reaches the narrow plain, about 20 feet above the sea, which, as already noted, lies behind the coastal hills in many places in this part of the Strip. The country bordering the Coolgardie-Esperance line has a similar profile, but the low-level plain is largely obscured by fixed sandhills.

The northern part of the Ravensthorpe-Hopetoun railway passes along a belt that is, as already noted, quite different from the "plain," but the southernmost 10 miles or so is over a scrub-covered plain about 100 feet above the sea.



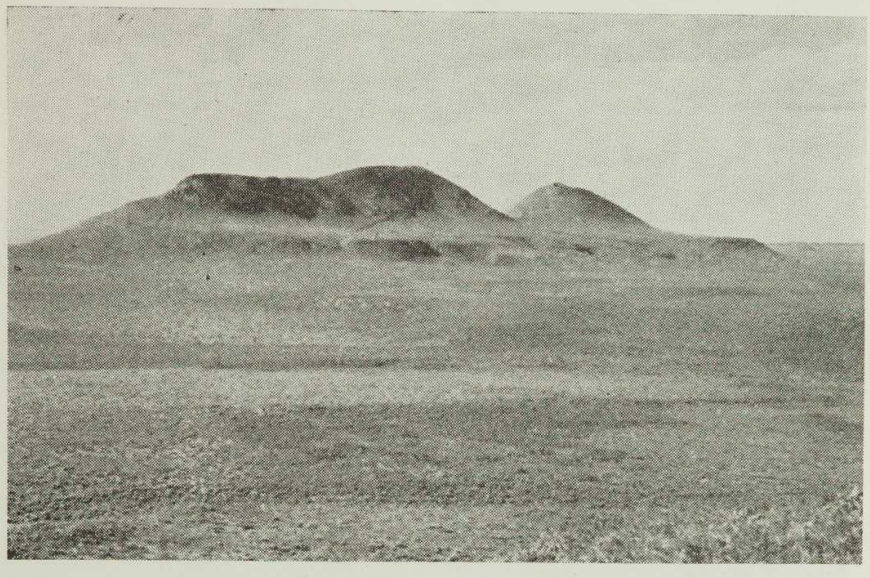
Text Fig. 20.

Platform on Mt. Ragged, with large rock which has probably rolled down from steep upper slope.

H. T. Phillipps, Photo.

The Israelite Bay-Norseman track crosses plain country above which rise many hills, of which Mt. Ragged (1920 feet) is the highest (text figs. 19–20). Mt. Ragged is a hogback completely surrounded by a platform from 200 to 500 yards wide along the sides of the mountain, the width increasing to about 60 chains at the north end. The platform slopes outwards at about 5° and is almost unbroken by gullies at the south and east sides of the mountain. At the north end, the platform is cut by two deep gullies, and, although it is broken by numerous gullies on the west side, its identity is very apparent when it is viewed from a distance. An even better-defined platform occurs, at the same height, round the Russell Range four miles to the north (text fig. 21), possessing similar characteristics to that on Mt. Ragged. The platforms on both Mt. Ragged and the Russell Range are cut through the highly inclined quartzites and schists, of which both are composed, and resemble the platforms on the coast between Middle and East Mt. Barren, which are however only about 250 feet. above the sea. Similar shelves, apparently at the 800 feet level, are visible from Mt. Ragged on other hills

to the east and west. We saw no waterworn pebbles or boulders on any of these shelves, but nevertheless it seems highly probably that they record former sea-levels. The Mt. Ragged and Russell Range shelves were possibly cut during the Miocene submergence (Clarke, Teichert, and McWhae, 1948, p. 98).



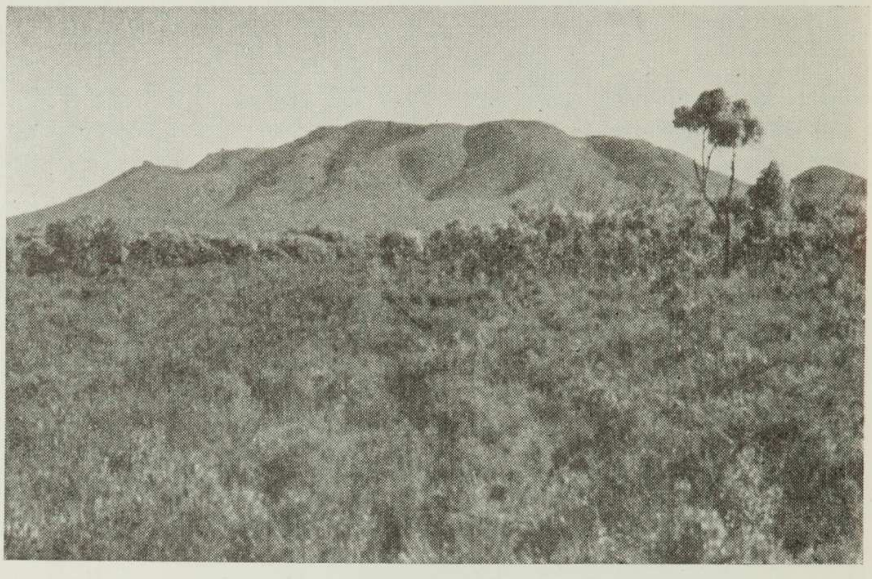
Text Fig. 21.

Probable wave-cut platform, Russell Range, at 800 foot level.
H. T. Phillipps, Photo.

Aneroid readings along the Norseman-Israelite Bay track show that here also the plain, which near Mt. Ragged, is about 500 feet above the sea, slopes southwards very gradually, until, seven miles from Israelite Bay where it is about 300 feet above the sea, it gives place to a slope of about 1 in 40, which leads down to the fixed-dune country on the N.W. side of the coastal lagoon already mentioned. A few miles east of this track there is no escarpment and the plain slopes gradually from about Mt. Ragged to the level of the coastal lagoon.

The track running westwards towards Esperance, north of C. Pasley, is over plain country, largely heath-covered, with many scattered hills, the plain being by aneroid 200 to 300 feet above the sea. Between the Pallinup R. and Green Range there is an approximately level surface 400 to 500 feet above the sea, whereas the plain country S.W. of Green Range and reaching nearly to Cheyne Beach, is on the average not more than 200 feet high. From Ongerup southwards to a line running about east from near Graves Hill, the general level is between 500 and 800 feet and the country gives the impression of being a somewhat dissected plain, but south of this there is a pronounced fall to the 200 to 300 feet level. The very mild scarp separating these two plains is visible for some distance trending east. The 200 to 300 feet plain (text fig. 23) seems to persist eastwards interrupted by valleys, to the Fitzgerald R., as far up as about 10 miles from the sea. A belt of level country, of about the same elevation (text fig. 22) separates the Middle Mt. Barren and Eyre Ranges from higher ground to the north, which is crossed by the road to Ravensthorpe, and which appears to be a continuation of the 500–800 foot plain near the Pallinup River. The Ravensthorpe-Esperance road,

once it has crossed the Ravensthorpe belt, lies over the plain. East of the Oldfield R. this plain is below the 200–300 foot level, which however, may well be present to the north of the road—country over which we have not travelled. The Esperance-Israelite Bay track is generally at the 200–300 foot level, which extends to the sea as far as Cape Pasley. Beyond this the track descends to the low-level (20 foot) plain, as already described.



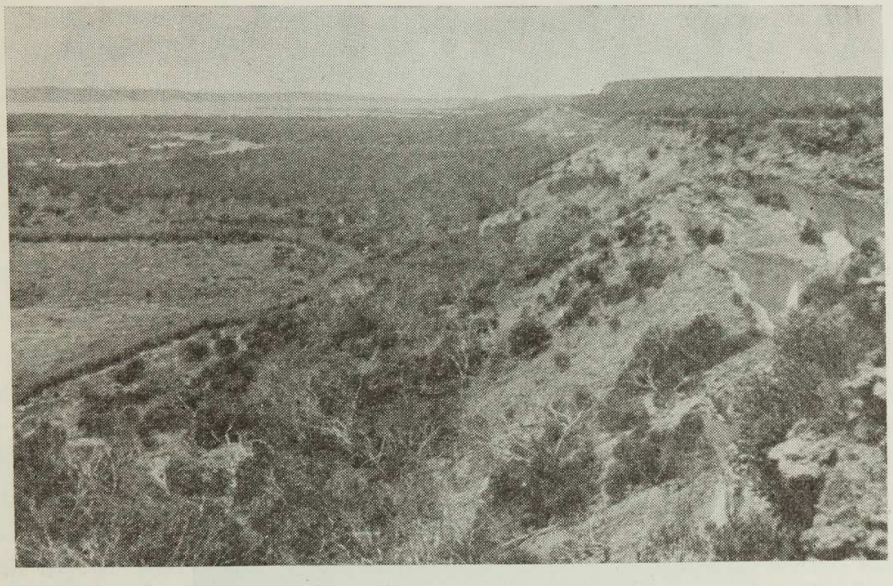
Text Fig. 22.

Typical low heath country north of Middle Mount Barren Range.

H. T. Phillipps Photo.

(b) Rivers.—Ten or more major "rivers" cross the eastern portion of the Strip. Their direction is in the main south-east, unlike those of the western part, which, in a general way, flow from north to south. There does not seem to be any trace of a senile east-west river system, such as Mr. Robert Smith has found in the western part. The drainage channels of this eastern portion carry running water more rarely than those of the western—a result, partly of the smaller rainfall, partly of the presence in the lower reaches of many of the streams of a considerable thickness of absorbent Plantagenet Beds, overlying the generally impervious Pre-Cambrian rocks; in most of them however pools of brackish or salt water are common. As we move eastwards from the Perth-Albany railway the watercourses become progressively shorter: thus the Kalgan and Pallinup Rivers head as far inland as many of those in the western part, the heads of the Gairdner, Fitzgerald, and others, as far east as Esperance, are apparently only a little way beyond the north edge of our map, except the Lort, which "extends far into the interior, draining the salt lakes of the Dundas Hills" (Woodward, 1894, p. 15); east of Esperance few drainage channels seem to persist as much as 10 miles north of the coastline, though shallow continuations may exist in the almost unmapped country farther north.

Where the valleys are in the horizontal Plantagenet Beds or (as in the middle part of the Fitzgerald) in a soft schistose phase of the Pre-Cambrian, the stream meanders over flats, seldom a mile wide, abutting against cliffs (text fig. 23); where the valleys are entirely in hard Pre-Cambrian rocks the sides slope rather gently down to the watercourse.



Text Fig. 23.

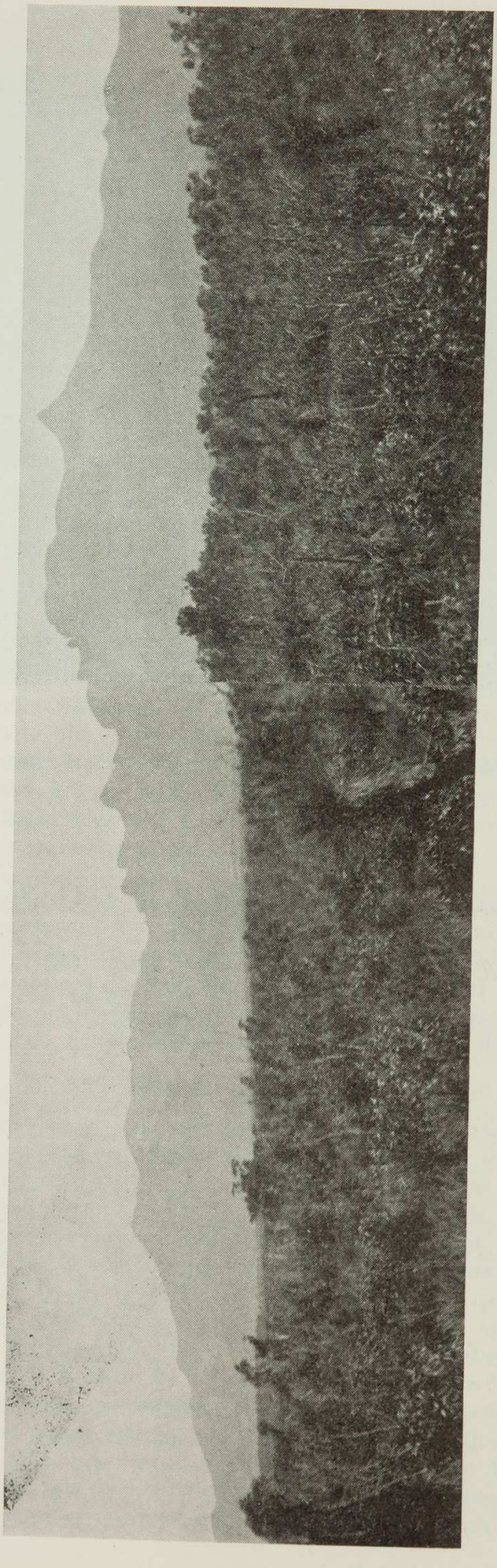
Cliffs of Plantagenet Beds on west side of Fitzgerald River, Fitzgerald Inlet in background.

H. T. Phillipps, Photo.

The river beds, wherever we have seen them, seem to have arrived at the base-level of erosion, and this characteristic is maintained where some of the rivers in the lower part of their course pass through steep-sided gorges, as for example the Phillips in its gorge through the eastern end of the Eyre Range, and the short St. Mary River (near Point Ann), and Willyun Creek (a little west of Cape Riche). Even the short gullies, that run S.E. off the Middle and East Barrens, have cut very deeply into the 250 foot platform that fronts the range.

A stream, probably a tributary of the Lort, crossed by the Ravensthorpe-Esperance road about 10 miles east of the Lort, is rather unusual in that it is at a different stage of development from the mature valleys of the neighbouring Lort and Dalyup. It lies in a trench, six feet deep, in the plain, which is about 200 feet above the sea, and has every appearance of being a very young, consequent stream, which has just begun to incise the plain.

(c) Lakes and Swamps.—The plains of the eastern part of the Strip are dotted with many small, shallow, unconnected lakes and swamps, some of which are shown on our map. Most of them are dry in summer, and in many the water is salt or brackish, but in a few, of which Pabelup, about six miles north of Mt. Bland, is an example, there is nearly always useful water. Swamps and lakes on the plain are particularly numerous between Esperance and Israelite Bay and are a serious hindrance to travel in wet weather. In the Kalgan-Pallinup district they are, Mr. Robert Smith suggests, possibly due to the removal in solution of calcareous matter from very fossiliferous patches in the underlying Plantagenet Beds. Supporting this suggestion, we noticed, near Warriup Homestead, about 39 miles N.E. of Albany, where the Plantagenet Beds are rather richly fossilferous, that there are several small crater-like hollows, which seem to be of the nature of swallow-holes. However, some of the lakes and swamps cannot be thus explained. For example, about seven miles north of Pine Hill, close to the Israelite Bay-Norseman track, is a circular salt-pan about five chains across, surrounded by a



Text Fig. 24.

Profile of east end of Stirling Range from the south.

H. T. Phillipps, Photo.

granite " cliff " about six feet high ; again, about seven miles S.E. of Howick Hill, on the Esperance-Israelite Bay track, is a completely enclosed bare surface of gneiss, about one chain across and two feet below the general level. We cannot suggest how these features originate.

(d) Water Supply.—There are many lakes, swamps, and rivers, nearly all salt or brackish, in the Stirling Region part of the Strip, and we have seen a map on which quite a number of " springs," etc., are shown. Actually, supplies of potable water are very small and scarce, except after rain, which quickly makes much of the country boggy and difficult to cross.

(e) Hills.—These have been mentioned in earlier parts of the paper, but attention might be drawn to the difference between the hills (Mt. Ragged, Russell Range, and others) at the east end of the Strip, and those farther west (Sirling Range, the Barrens, and Eyre Range) ; the western group have not the 700–800 foot shelf, which is a striking feature of the eastern-most hills (text fig. 21). There is, indeed, a shelf on the Barrens (text fig. 9) but it is about 250 feet above the sea and is only on the south side. We have not noticed, nor does Woolnough (1920) record, any feature of this kind in the Stirling Range (fig. 24).

IV. CONCLUSION.

The area discussed consists of two rather distinct parts—a western, which probably continues to Cape Leeuwin, and an eastern, which gives place to the Nullarbor Region, not far east of Israelite Bay.

The western part is a dissected plateau of Pre-cambrian rocks, drained by south-flowing, rather young rivers, but having also the remains of an older east-west drainage. The adjacent sea-floor, at about 20 miles south of the coastline, slopes steeply to 1,000 fathoms or more, and the continental shelf carries but few islands.

The eastern part is, on the average, distinctly lower than the western. It is essentially a plain in which there are two or more steps, and above which many island-like hills of Pre-Cambrian rocks rise to various heights. Some of the hills were islands, others were submerged rocks in the Miocene sea, which covered the land to a depth of at least 900 feet, as evidenced by the Miocene rocks at Norseman, 100 miles north of Esperance.

The sea-floor off the eastern part is extremely irregular, and is studded with islands for 30 miles or so to the south ; beyond which it probably plunges steeply, as in the western part ; the various heights of the protrusions of Pre-Cambrian bed-rock through the Miocene—some barely uncovered, others still buried, show that the bed of the Miocene sea was also very uneven.

Coastal Limestone does not, so far as we know, occur on the mainland east of long. 120 E. but is reported from some of the islands of the Recherche Archipelago. This suggests that the coastline of the eastern part of the strip has retreated after the formation of the Coastal Limestone, whereas the western part has remained stable. The retreat of the eastern part, if verified, is most plausibly ascribed to earth movements, which did not occur in the western part.

Platforms, at heights ranging from 800 to 200 feet and less above present sea-level, indicate, as do the steps on the plain, that there were several pauses in the emergence of the present land surface. Apparently such shelves are not recognizable in the Stirling and Porongorup Ranges, or in the western

dissected plateau ; this suggests that some large dislocations separate the western part from the eastern,—in which connection Woolnough's horst theory of the origin of the Stirling Range should be noted.

Fixed sand dunes at various heights, some 200 feet or more above sea-level, and the wide distribution of a cuirass of laterite or duricrust, indicate that the present cycle was preceded by a more arid one, during which, perhaps, the marginal deposits of calcareous sandstone, now compacted into Coastal Limestone, were formed. Sea-built accumulations of sand, etc., at, or close to, present sea-level, and the fact that all valleys are at grade along the coast-line, show that the present cycle has long been in existence.

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